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(54) STRAIGHTENING OF VANES

(71) We, CHROMALLOY AMERICAN CORPORATION, a corporation organized and existing under the laws of the State of Delaware, United States of America, of Orangeburg, New York 10962, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to the restoration of distorted vanes and, in particular, to a method and apparatus for straightening guide vanes comprising an airfoil section having locating buttresses at opposite ends thereof.

Nozzle guide vanes in jet engines are subjected in service to high temperatures and aerodynamic loading conditions over long periods of time as a result of which deformation and distortion of the airfoil section occur relative to reference mounting surfaces, e.g. relative to the locating buttresses of the vanes. In order to restore the vane part to its original shape and proper locating geometry, a hot forging technique is employed involving the use of a multiple cylinder hydraulic press employing heated precision shaped dies whose contoured working surfaces, when clamped together about an airfoil section, define the desired shape to be achieved.

The restoration operation employed in conventional practice resides in the use of heated contoured dies suitably oriented and restrained by means of die holders so as to provide an airfoil shape having the proper attitude with respect to the locating surfaces, such as the locating buttresses at the opposite ends of the airfoil section. The restoration is normally achieved in a die closing cycle where the die assembly opens to receive the vane, clamps the

locating surfaces (the buttresses) between references and then closes the dies onto the airfoil section. Shimming the die blocks to effect straightening and rotation of the blocks results in opening or closing of the apparent nozzle throat area. The disadvantage of this method is that it relies on the actual vane dimensions, including the buttresses, for referencing during hot forming of the part and, because of this, it is difficult to ensure accurate seating of the die uniformly on the vane to be straightened.

The foregoing difficulty is overcome by means of the invention as will be apparent from the following disclosure and the accompanying drawings, wherein:

Fig. 1 is a detail rendition of the essential parts of one embodiment of the hydraulic press which may be employed in carrying out the restoration cycle;

Figs. 2 to 5 are illustrative of the various stages or steps which make up the restoration cycle;

Fig. 6 represents schematically one embodiment of the apparatus for carrying out the invention; and

Figs. 6A and 6B illustrate another embodiment which may be employed in straightening the airfoil section and, in particular, the buttresses thereof.

Stating it broadly, the novel aspects of the invention reside in a more simplified restoration cycle in which only the airfoil section is gripped during the straightening cycle so that the airfoil section is straightened first, following which during the period the airfoil section is still under pressure, the buttresses are oriented to their correct position relative to the straightened airfoil section. Thus, the ultimate referencing is determined by the airfoil

section itself and not initially by the use of positive stops applied to the buttresses as normally employed conventionally. The novel method employed enables the heated dies to seat on the airfoil section as it exists instead of at some predetermined position. This is desirable because part tolerance levels are of sufficient magnitude to prevent setting of positive stops in a manner which is suitable for all parts, since each vane is formed differently from the other. By carrying out the steps of the cycle sequentially with respect to time during the application of pressure so that the proper dwell is obtained during each part of the cycle, the straightening is achieved expeditiously and simply, particularly at each of two specific steps, to wit: (1) the step of first reforming the airfoil to the correct shape and profile without simultaneously indexing the position of the locating buttresses; and (2) the next step of orienting the locating buttresses to the straightened or corrected airfoil, these steps being individually controlled.

One embodiment of the invention broadly stated resides in a method for restoring a distorted vane to its original shape for proper location in a final vane assembly, the vane comprising an airfoil section having locating buttresses at opposite ends thereof which comprises, clamping the airfoil section of a heated vane under deforming pressure between heated opposed contoured dies having contoured working surfaces defining the desired airfoil shape with the buttresses of the vane extending freely outside the clamped dies, the closure of the dies being determined by the die configuration and the shape and thickness of the airfoil section in the die, maintaining the deforming pressure on the heated vane until the airfoil thereof has conformed to the airfoil configuration defined by the dies in the clamped position and then, while maintaining the airfoil section under pressure between the dies, orienting the freely extending buttresses relative to the corrected airfoil section to the attitude required for proper location of the vane in the final vane assembly. Positive indexing stops are provided which limit the override of the contoured dies.

In its more specific aspects, the method comprises providing a pair of moveably opposed heated upper and lower contoured dies whose working faces when clamped together define the contour of the desired airfoil shape, the lower die having separately positioned on each side thereof locator pads for locating and indexing each of said opposed buttresses to the desired attitude during a restoration cycle, placing a heated vane on the heated lower die with the dies in open position and with the buttresses of said vane extending freely outside the confines of the die, the lower die being raised relative to the locator pads to allow clearance between the extending buttresses of the vane and said locator pads dur-

ing the airfoil straightening step, clamping be-
airfoil section of the heated vane under de-
forming pressure between the upper and lower
dies, the clamping of the dies being deter-
mined by the die configuration, maintaining
deforming pressure on the airfoil section until
the heated airfoil section has been restored to
the desired configuration defined by the con-
toured dies in the clamped position, causing
the clamped lies to move as an assembly to-
wards the locator pads until the extending
buttresses are pressed against the locator pads
and are oriented to the desired attitude rela-
tive to the airfoil section, and then separating
the dies and removing the restored vane there-
from. Opposing upper and lower locator pads
may be employed so that when the clamped
dies move as an assembly to the lower locator
pads, upper locator pads are brought down
with the upper dies, whereby, at the end stroke
the buttresses are clamped between upper and
lower locator pads.

As illustrative of one embodiment of a mul-
tiple cylinder hydraulic press that can be
employed in carrying out the invention, refer-
ence is made to Fig. 1 which shows a pair of
spaced platens 10 and 11, mounted on sup-
ports (not shown), the platens having centrally
located openings 12 and 13 provided inter-
nally with annular shoulders 12A, 13A for sup-
porting journals 14 and 15. Platen 10 has
extending downward from it, locator pad sup-
ports 10A, 10B; while platen 11 has up-
wardly extending locator pad supports 11A,
11B. The journals have slidably mounted in
each stub shafts 16 and 17, respectively, shaft
16 being integral with die holder 18, and
shaft 17 being integral with die holder 19.
Die holder 18 is connected to upper die block
20 by means of bolts 22, 23 and centering pin
24, the connection being such as to provide
some articulation of the die block to ensure
adequate seating between the die block and
the workpiece.

Die holder 19 is similarly connected in
articulation relationship to lower die block 21
via bolts 22A, 23A and centering pin 24A.
The articulation provides for slight movement
of the die block as it seats against the work-
piece.

The upper and lower die blocks are actu-
ated into the forging position relative to the
vane via upper forge piston 25 and lower
forge piston 26 through hydraulic cylinders
not shown (note, however, the schematic of
Fig. 6). The upper die is brought into clamp-
ing position with the lower die via clamping
pistons 27 and 28 (operable by means of
hydraulic cylinders not shown), die assembly
stops being provided in the form of down-
wardly extending columns 29, 30 which are
adapted to abut correspondingly upwardly
extending columns 31 and 32. Hydraulic
pressure is applied to the dies via upper and
lower forge pistons 25 and 26 to effect

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- straightening of the airfoil section. Locator pads 35 and 36 are provided on supports 11A and 11B on each side of lower die 21 against which vane buttresses 33 and 34 are oriented during the final restoration step. Upper locator supports 10A and 10B may have locator pads integral therewith similar to 35 and 36 (not shown), but note Figs. 6, 6A and 6B).
- Figs. 2 to 5 show schematically each step of the restoration cycle, equivalent parts being designated by the same numerals as in Fig. 1, only those parts being shown essential to understanding the process.
- Referring to Fig. 2, the die assembly is shown open or in home position, the stops 29 and 30 being depicted separated from lower stops 31 and 32. The heated vane is placed on lower die 21 in the raised position due to the action of piston 26, only the airfoil section 37 being supported by the die, with buttress 34 extending freely outside of the die. Since the airfoil is shown in cross section, the other buttress 33 is not visible in the drawing. The lower die is in the raised or home position to receive the part and to allow buttress 34 to be supported clear of buttress locator pad 36. The position of the airfoil part on the lower die is indicated by axes X—X and Y—Y.
- Upon actuation of the cycle, the die assembly is allowed to close against the stops as shown in Fig. 3, thus establishing the location of upper and lower die blocks in space with proper alignment. As will be noted, at the stop setting, clearance 38 is provided between upper die 20 and the upper surface of the airfoil section. The lower die remains fixed in the raised or home position under the influence of pressure in the lower actuating cylinder shown schematically in Fig. 6.
- In Fig. 4, the upper heated die block 20 is driven downward under controlled cylinder pressure (note Fig. 6) to take up clearance 38 and until the airfoil section is clamped between upper and lower heated die blocks. This forged position is maintained under pressure for a suitable time until the airfoil section is reformed to the configuration of the contoured blocks.
- Following the foregoing forging step, the pressure in the cylinder holding the lower die block in place is reduced, allowing the upper cylinder to drive both die blocks as an assembly downward at a controlled rate, while still maintaining a clamping force on the airfoil section (note Fig. 5). Thus, the airfoil section which is continually held between the die blocks under pressure is driven downward so that the buttresses are pressed against the locator pads e.g. 36 set at the attitude to orient the buttresses to the position required for proper location in the final vane assembly.
- As will be noted, the airfoil section is first straightened and the buttresses are then oriented to the correct attitude relative to the straightened airfoil section. The buttresses of the vane are maintained in the position against the locator pads until they are re-oriented as desired. After a predetermined time in this position, the sequential operation continues wherein the press cycle is halted, the die assembly opened or returned to home position and the part removed. The method does not rely on actual part dimensions for referencing, the forging pressure being applied directly to the airfoil section being reformed, following which the freely extending buttress is then oriented relative to the reformed airfoil section.
- By employing the broadly stated dual cycle type of operation, the airfoil is straightened and caused to be rotated as desired between the contoured faces of the articulated dies without the influence of restraint normally created by distorted buttresses. By maintaining the buttresses in freely extending or floating position outside of the dies, they can thereafter be restored to the proper attitude without interference with the straightened airfoil section.
- Adjustment for apparent nozzle throat area is produced by allowing more or less force to be applied between the upper and lower heated die blocks by adjusting the hydraulic pressure. A simple servo type follow-up system can be employed to track the airfoil motion and make such adjustments as required to produce a given shape.
- Fig. 6 shows schematically how a press cycle can be programmed using a cycle control timer coupled to hydraulic fluid reservoir or source 42 for providing the sequencing and motivating pressure required to exert forces through cylinders 45, 46, 47 and 48. In operation, solenoid actuated valves V1, V2 and V3 in lines 43, 44 and 44A are used for controlling the flow of fluid to hydraulic cylinders 45, 46, 47 and 48; cylinders 45 and 46 having upper and lower pistons 46A and 45A, respectively, coupled with respect to piston 46A to die holder 49 of upper die 50 and also coupled with respect to lower piston 45A to die holder 51 of lower die 52. Buttress locator pads 53 and 54 are disposed on each side of lower die 52, the lower die in home position being slightly above the pads. Clamping cylinders 47 and 48 may have locator pads 53A and 54A for gripping opposing pads 53 and 54 to be described later in one embodiment.
- In starting a cycle, the power is turned on to actuate a conventional cycle control timer 41 having a train of cams which rotate to define a complete cycle, each cam being set to carry out a particular step of the cycle. Thus, as the switch is closed and the cycle control timer is actuated, the die assembly, which is already open, closes via solenoid

V1 upon a vane placed in the lower die, the lower die 52 remaining fixed in the raised or home position under the influence of pressure from lower cylinder 45 fed by solenoid actuated valve V3 determined by cycle controller 41, forging pressure being then applied to upper contour die 50 via solenoid actuated valve V2. As the upper die is driven downward under controlled hydraulic pressure, the airfoil section is clamped between the dies 50 and 52, the timer being set to continue the clamping pressure until the airfoil section is reformed. Depending upon the series of vanes being reformed and the particular alloy composition thereof, this is predetermined by a set of preliminary runs.

At the end of a given time period predetermined by the timer, the pressure in the lower cylinder 45 is reduced by actuation valve V3, thereby allowing upper cylinder 46 to drive both die blocks downward as an assembly at a controlled rate while still maintaining the part under forging pressure. When the buttresses of the part reach locator pads 53, 54 (note also Fig. 5), the vane is pressed against the locator pads set at the attitude desired for orienting the buttresses relative to the straightened or reformed airfoil section. The amount of time necessary to achieve the desired orientation is predetermined by the timer. At the end of this step, the press cycle is halted in accordance with the setting on the timer and the assembly allowed to open to enable removal of the part, the timer resetting itself for the next cycle.

When the clamping pistons 47A and 48A are brought down, the upper die 50 is brought down with them. However, in the aforementioned cycle, upper locator pads 53A and 54A (note dotted lines) are not employed and the clamping assembly does not contact the buttresses.

However, in an alternative embodiment, after the upper and lower dies 50 and 52 are brought in forging contact (note Fig. 6A), with the aerofoil section, the lower cylinder 45 is reduced by actuation of valve V3, thereby allowing the upper cylinder 46 to drive both blocks and platen 10 downward as an assembly at a controlled rate while maintaining the part under forging pressure until the buttresses engage against the lower locator pads. Clamping pistons 47A and 48A thereafter bring down platen 10 and upper locator pads 53A and 54A, whereby the buttresses are gripped on opposite sides by upper and lower locator pads 54A, 54 on one side and upper and lower locator pads 53A and 53 on the other side to twist the buttress into the correct attitude relative to the airfoil.

The alternative embodiment is shown in Figs. 6A and 6B. In Fig. 6A, the airfoil is undergoing the forging step. At this point, there is a dwell during which lower locator pad 53 and upper locator pad 53A are spaced

away from the buttress 34A. Upon completion of the forging step as determined by the cycle control timer, upper die 50 is caused to move down still further as valve V3 is released, whereby lower die 52 likewise moves down until buttress 34A is gripped between locator pads 53 and 53A to twist the buttress in the correct attitude relative to the straightened airfoil section.

An alloy composition employed in the vane is one containing by weight 11.0% W, 1.75% Fe, 0.45% C and the balance substantially cobalt. The forging temperature employed for such alloys may range from 1900°F to 1700°F. Generally speaking, the forging temperature is maintained at 1800°F. The upper and lower dies are maintained at a temperature close to that of the vane, that is, from 1800°F to 1600°F, generally 1700°F. The upper and lower dies are preferably made of a heat resistant alloy. The composition of such an alloy is as follows: 0.6% W, 18.5% Fe, 0.20% C, 9.0% Mo, 1.5% Co, 22.0% Cr and the balance essentially nickel.

WHAT WE CLAIM IS:—

1. A method for restoring a distorted vane to its original shape for proper location in a final vane assembly, said vane comprising an airfoil section having locating buttresses at opposite ends thereof, characterized in clamping the airfoil section of a heated vane under pressure between heated opposed dies having contoured working surface defining the desired airfoil shape with the buttresses of said vane extending freely outside the clamped dies until the airfoil shape thereof has conformed to the airfoil configuration defined by said dies, and then, while maintaining said airfoil section under pressure between the dies, orientating the freely extending buttresses relative to the airfoil section to the attitude required for proper location of the vane in the final vane assembly.

2. A method as claimed in Claim 1, wherein the closure of the dies is determined by the shape and thickness of the airfoil section.

3. A method for restoring a distorted vane to its original shape for proper location in a final vane assembly, said vane comprising an airfoil section having locating buttresses at opposite ends thereof, characterized in providing a pair of movably opposed heated upper and lower contoured dies whose working faces when clamped together define the contour of the desired airfoil shape, said lower die having positioned on each side thereof locator pads for locating and indexing each of said opposed buttresses to the desired attitude during a restoration cycle, placing a heated vane on the heated lower die with the dies in open position and with the buttresses of said vane extending freely outside the confines of said die, said lower die being raised relative to said locator pads to allow clearance between the extending buttresses of the vane and said

locator pads, clamping the airfoil section of said heated vane under pressure between said dies, maintaining pressure on the airfoil section until said heated airfoil section has been restored to the desired configuration defined by the contoured dies in the clamped position, causing said clamped dies to move as an assembly towards the lower locator pads until the extending buttresses are pressed against said pads and are orientated to the desired attitude relative to the airfoil section, and then separating the dies and removing the restored vane therefrom.

4. A method as claimed in claim 3, wherein said lower and upper dies each have positioned respectively on each side thereof upper and lower locator pads for locating and indexing each of said opposed buttresses to the desired attitude during a restoration cycle, said upper die having means associated therewith for supporting said upper locator pads and for bringing said upper locator pads towards said lower pads, and including bringing said upper locator pads into operable relation with said lower pads until the extending buttresses are pressed between said pads and are orientated to the desired attitude relative to the airfoil section.

5. An apparatus for restoring distorted vanes to their original shape, said vanes comprising an airfoil section with locating buttresses at opposite ends thereof, characterized in a pair of oppositely disposed upper and lower dies located one above the other, the working faces of said dies in the clamped closed position defining the desired airfoil configuration, lower buttress-locating pads positioned on each side of said lower die, said pads being located in the path of travel of the vane buttresses during a restoring cycle, the home position of said lower die being slightly above said pads, means for moving said dies relative to each other to a closed position and together as an assembly while in the closed position in the

direction of said lower buttress-locating pads, stop means associated with said apparatus for avoiding overriding of said dies during a restoration cycle, and means for applying forging pressure to said dies in the closed position.

6. An apparatus as claimed in claim 5, wherein said upper die has upper buttress-locating pads located on each side thereof, said pads being on supports which move downward with said upper die for cooperation with said lower locating pads.

7. An apparatus as claimed in claim 5, including a cycle controller with a timing circuit for effecting sequential operation of said restoring cycle, such that when a heated vane is placed in the lower die and the cycle actuated, the dies which are heated are caused to close on said vane, forging pressure is applied for a predetermined time to the vane, the closed die assembly then caused to move towards the lower buttress-locating pads to orientate the buttresses of the vane to the correct attitude, following which the dies are actuated to return to their home position for removal of the restored vane from the lower die.

8. An apparatus as claimed in claim 7, wherein said upper die has upper buttress-locating pads on each side thereof which cooperate with the lower locating pads when the closed die assembly is caused to move towards said lower locating pads.

9. A method for restoring distorted vanes to their original shape, substantially as described with reference to the accompanying drawings.

10. Apparatus for restoring distorted vanes to their original shape, substantially as described herein with reference to the accompanying drawings.

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FIG.1.

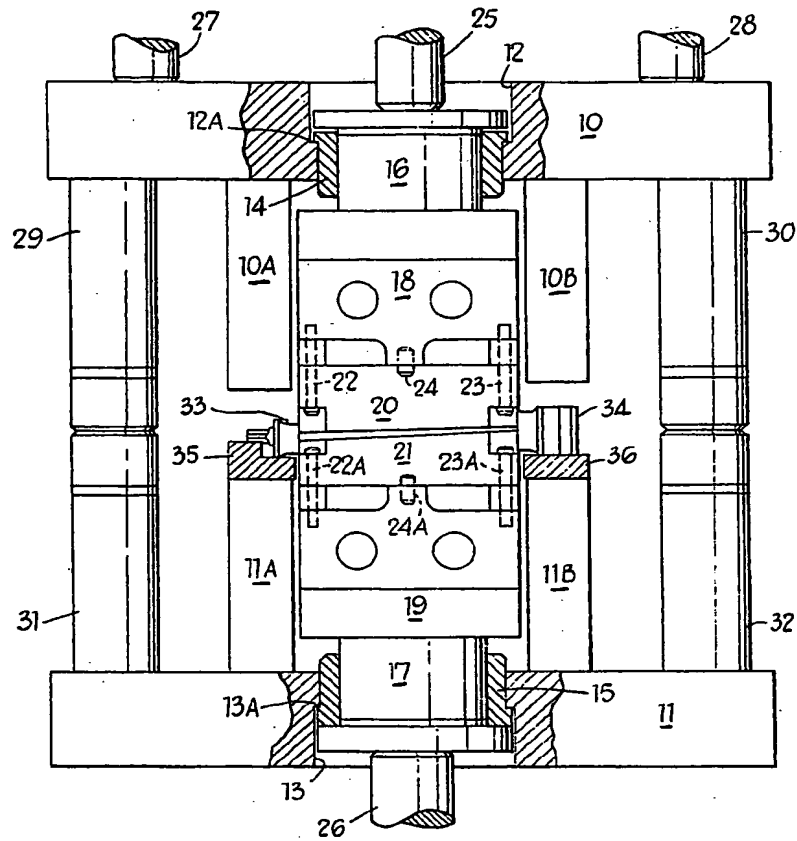


FIG.2.

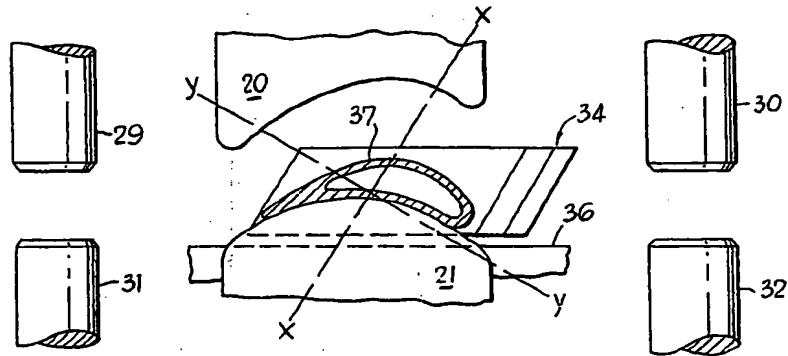


FIG.3.

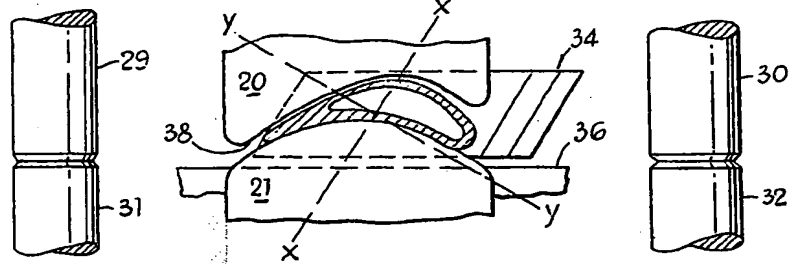


FIG.4.

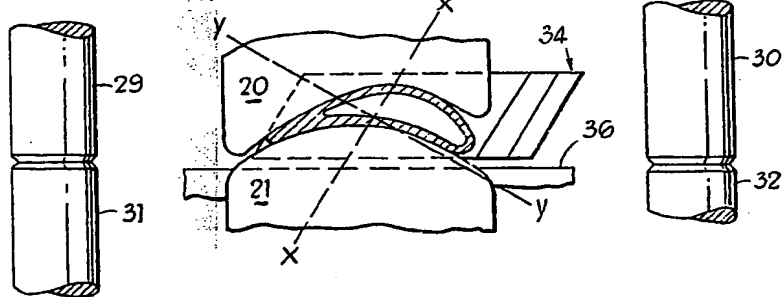


FIG.5.

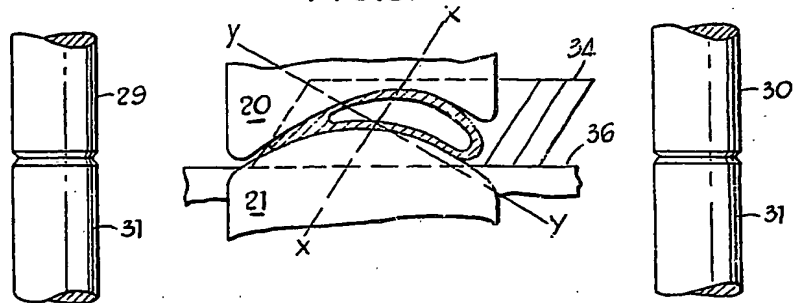


FIG.6A.

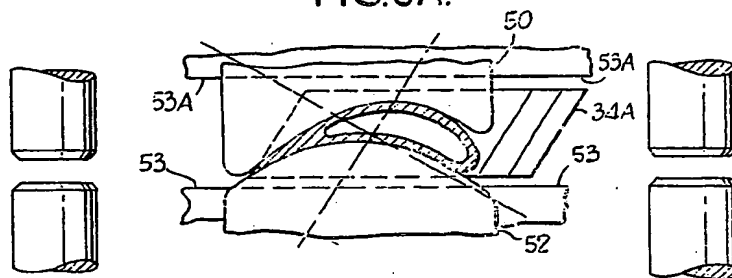
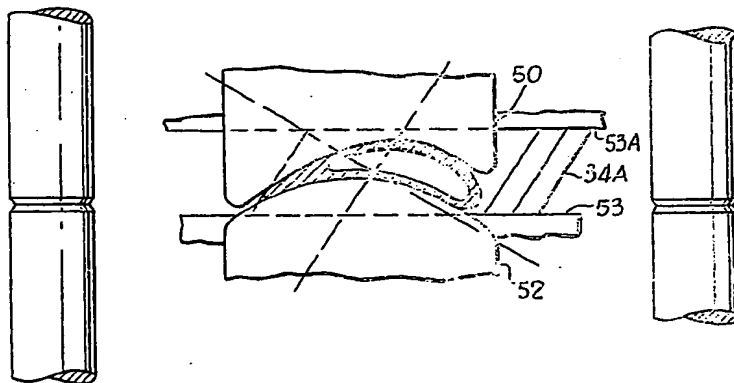


FIG.6B.



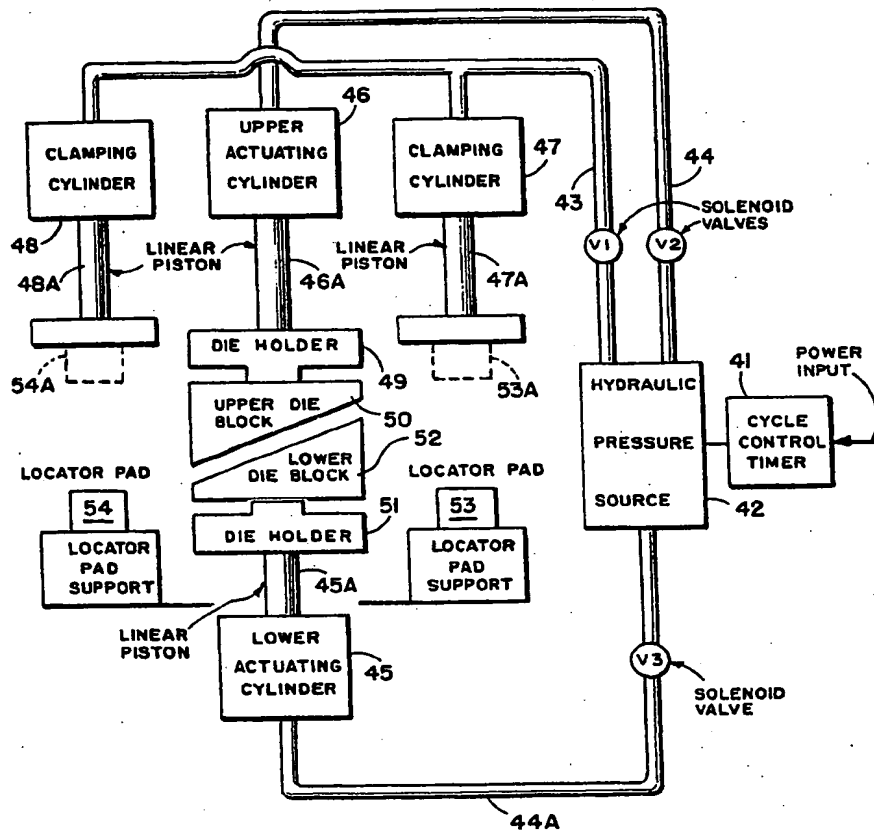


FIG. 6